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A. C. TRUE, Director.

PRELIMINARY PLANS AND ESTIMATES FOR DRAINAGE OF FRESNO DISTRICT, CALIFORNIA.[1]

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THE OBJECT OF THE SURVEY.

The object of the investigations made by the Office of Experiment Stations of the Department of Agriculture in the vicinity of Fresno, Cal., during the summer of 1902, was to secure data from which plans for the drainage of surplus underground water could be intelligently made. The necessity for such drainage has been forced upon the attention of all observing fruit growers and vineyardists. The facts are patent to everyone, but the particular remedy to be applied has not been so clear by reason of the extent of territory involved, the surface and soil conditions peculiar to the section, and the elaborate improvements which have become an essential part of the Fresno surroundings. All of these and possibly other conditions must be taken into consideration in the development of any practical drainage plan.

The facts which emphasize the necessity of drainage and the difficulties to be met in securing it may be briefly enumerated. The lower soil which formerly was dry and afforded ready drainage for water leaking from irrigating canals and that furnished by overirrigation of lands which they serve, has become filled with water which shows at the surface in the lower areas and at varying heights in the soil over the entire tract of cultivated land. This water table or plane of saturation is not infrequently found within 2 feet of the surface, though its height is variable during the growing season. The effect of this condition is to injure growing crops in two ways. First, by reason of an excess of water in the soil, which is everywhere and at all times a hindrance to the proper growth and development of useful plants. It rots the roots of trees and vines and limits the productive depth of the soil to that portion lying between the water table of the soil and the surface, thus cutting off a large part of the available fertility peculiar to the soil of this district. Second, by reason of the excess of alkali

[1] This report is based on surveys and plans made in 1902 by Prof. O. V. P. Stout, agent and expert, under the direction of Prof. Elwood Mead, Chief of Irrigation Investigations, and is preliminary to a more complete report to be made hereafter.

which the abundance of water has dissolved from the soil and which, through the process of evaporation, has become concentrated at or near the surface. This deposit has not been made in one or two years only, but is the result of successive annual accumulations until in many localities entire vineyards have been destroyed and others are in the various stages of decline. That the evil is growing and threatens the final destruction of thousands of acres of valuable vineyard land is shown by the observations and opinions of the most careful cultivators.

WILL DRAINAGE BE BENEFICIAL?

That drainage will remedy the evils mentioned, and particularly that it will arrest the inroad of alkali and furnish a means for the reclamation of land already injured from this cause, has been shown in many publications of the Bureau of Soils of this Department and of the California Experiment Station. The following local instances of the beneficial effects of lowering the soil water are instructive in this connection:

Land which adjoins deep drainage channels, as the Selma Ditch or Kings River at Reedley, or land which occupies the higher portions of the cultivated area is comparatively free from surface alkali. The example found in what is known as the Selma Sand Hollow, a name which is frequently used in referring to the most pronounced of the ranges of depressions which are embraced in the area surveyed, located in T. 16 S., R. 22 E., furnishes a striking illustration of the success of drainage experiments. About fifteen years ago a number of interested land owners became alarmed at the rise of the ground water in that locality and combined in making this depression continuous by excavating through the low, short bars which separated the ponds from one another, thereby providing cheaply a drainage channel which has been in effective operation ever since. The deep tule ponds situated in various localities contain an abundance of seepage water which is derived from land adjoining them and act as drainage receptacles giving, for the present at least, satisfactory drainage of the soil. As a rule the more level lands and those which lie farthest down the slope are those which suffer most from the effects of alkali.

EXTENT AND RESULTS OF THE SURVEY.

The survey made by the Office of Experiment Stations in the Fresno district was confined to a study of the engineering problems involved in the proper drainage of this region, and its results are intended to show what may be done to alleviate similar difficulties in irrigated regions where like conditions are found.

The survey made during the summer and fall of 1902 covered a territory of 300 square miles, and was made for the purpose of determining the surface slopes, investigating the position and kind of hardpan, the

plane of subsoil water, the action of existing drains, and the character of such drainage water as could be obtained. Much information bearing upon the problem was obtained and is used in forming conclusions relating to the value and methods of drainage.

The territory demanding the most urgent and immediate drainage is that lying directly south and southwest of the city of Fresno, comprising about 28 square miles of highly cultivated vineyard land, or that which has been such. The surface slopes westerly, and in some instances southwesterly, about 5 feet per mile. The main irrigating canals extend in the direction of the greatest slope and parallel each other at intervals of from three-quarters to one and one-half miles. There is no drainage outlet nearer than the Fresno Slough, which is 15 miles distant, southwesterly from the city of Fresno. The district for which surveys and estimates have been made is bounded as follows: Beginning at the intersection of California and Chestnut avenues, which is the northeast corner of the district; thence westerly along California avenue; thence southwesterly on the south side of the ridge to Cornelia and Fresno avenues; thence south on Cornelia avenue to Washington avenue; thence east on Washington avenue, across the Southern Pacific and Santa Fe railroads to the southeast corner of sec. 32, T. 14 S., R. 21 E.; thence north on the east line of secs. 32 and 29 to North avenue; thence west to Chestnut; thence north on Chestnut to California avenue, the place of beginning.

DEPTH AND FREQUENCY OF DRAINS.

From investigations made here and elsewhere relative to the drainage of irrigated land which has become wet by seepage, it is learned that shallow drains, by which are meant those from 2 to 3½ feet deep, do not prevent the rise of alkali to the surface, nor in many cases make the land sufficiently dry for the most profitable cultivation. A depth of from 5 to 7 feet for main drains, it is believed, will lower the water line to such a point that the accumulation of alkali at the surface will cease; and when once the surface excess is disposed of by the well-known methods of irrigation and cultivation, the land will be permanently restored.

The distance apart at which the drains should be placed is one-half mile in east and west parallel lines. At this distance they will be accessible to owners of land on either side without great difficulty; and further, it is believed that they will reduce the water level uniformly over the entire area with the exception of such portions as have a persistent hardpan stratum at a depth less than that of the drains.

GENERAL PLANS.

While the depth and distance apart at which it is wise to place the main drains are quite clear, as determined by examinations so far made,

there may be a choice of the kind of drains which it would be proper to use for the main drainage. Underdrains constructed of draintile have been sufficiently well tested at Fancher Creek Nursery and Sunnyside Vineyard to prove that soil water will readily reach them and flow away when an outlet is provided; and further, that they will reduce the water level to a level approaching that of the floor level of the drains for a distance not yet determined. Deep, open ditches, when kept in good condition, will relieve adjacent land of seepage and drainage water. In either system the water must be disposed of constantly and not permitted to accumulate and back up in the drains, thereby raising the water line in the soil between them and partially defeating the object of their construction.

PLAN NO. 1.—OPEN-DRAINAGE SYSTEM.

The open system for the district described must have an intercepting outlet drain at the west which will receive and carry all water coming from the district in a southwesterly direction toward Fresno Slough. It should begin at the west side of sec. 17, T. 14, R. 20, extend southwesterly, as shown upon the map, in the direction of the greatest slope of the land a distance of 6 miles, having a full depth of 7 feet; then with a grade of 1½ feet per mile for 2 miles, until the water is discharged upon the surface of the ground at a point 40 feet lower than the surface of the land where it started. This drain should be 12 feet wide on the bottom, with side slopes of 1 to 1 for the entire distance. It may be added that this ditch will be in line to receive drainage from the city of Fresno, as well as from the district.

The drains for the district will consist of eight parallel, open drains, one-half mile apart, extending from the eastern boundary of the district directly west to the intercepting drain. They will have an average grade of 5 feet per mile; will be from 5 to 8 feet deep, 4 feet wide on the bottom, side slope of 1 to 1, and not less than 20 feet wide across the top. They will be constructed on one side of the avenues or roads, the excavated earth being thrown into the road and made into an embankment next to the property line. Where the ditches cross roads, bridges must be built; where they intersect irrigating canals, drains may be carried underneath by boxing or sewer pipe; where they come in front of and cut off entrance to private property, bridges must be built or the drain must be boxed and covered. Where the ditches cross railroad lines, large cast-iron culvert pipes may be used. All of these contingencies must be provided for as well as the cost of right of way, where, in some cases, the ditches do not follow roads.

The carrying out of this plan will involve the construction of 8 miles of intercepting outlet ditch and 65½ miles of interior or lateral ditches. The estimate of the cost of this work, including bridges, right of way

where public roads do not exist, organizing, legal and other expenses may be stated as follows:

Estimate for open drains.

INTERCEPTING OUTLET.

6 miles of ditches, bottom width 2 feet, depth 7 feet—25,977 cubic yards per mile at 15 cents	$23,379.00
1 mile of ditch, bottom width 12 feet, depth 5 feet—16,579 cubic yards at 10 cents	1,658.00
1 mile of ditch, bottom width 12 feet, depth 3 feet—8,817 cubic yards at 10 cents	882.00
	25,919.00

LATERAL DRAINS.

[Estimate per mile.]

Average depth 7 feet, bottom 4 feet, side slopes 1 to 1—15,048 cubic yards at 15 cents	$2,257.00	
2 highway bridges at $75	150.00	
6 farm entrance bridges at $50	300.00	
	2,707.00	
65½ miles at $2,707		177,308.00
23 boxed crossings for irrigation canals at $50		1,150.00
Railroad-iron pipe culverts		6,500.00
Right of way 23¾ acres at $150		3,563.00
		214,440.00
Organization, engineering, superintendence, etc., 10 per cent		21,444.00
Total		235,884.00

The construction difficulties which will be encountered in the execution of this plan are of a somewhat uncertain nature. It will be necessary to make the excavations during the fall and early winter when the soil water is at its lowest stage. The intercepting ditch can probably be constructed with a floating dredge more expeditiously and cheaply than by any other method for the reason that sufficient water will likely be developed for floating the machine, in which case the work can be done at any season of the year. The parallel ditches may probably be made either wholly or in part by dry-land machines. A part of this work, however, will consist of the proper placing of the excavated earth in the form of road embankments. Hardpan will be an undetermined factor in the work, as will also spots of water-bearing soil or quicksand.

The careful cleaning and care of these ditches will be essential to their efficiency for they must be kept clear and in condition to permit a ready flow of water over the bottom at all times. The loose character of the soil and the rapid growth of vegetation will make this a work requiring constant vigilance.

PLAN NO. 2.—COVERED OR TILE-DRAIN SYSTEM.

The tile-drain system will not require the open intercepting drain as an outlet. For this system the territory is divided into 18 subdistricts,

averaging in size from 800 to 1,700 acres. Lines of tile ranging from 8 inches to 22 inches in diameter are laid in parallel lines along the avenues corresponding to the system described for open ditches. The ditches do not cross irrigation canals, except in a few instances. The discharge from the drains is received in a sump located near a canal, and is then lifted into it by a plant consisting of a suitable pump operated by an oil engine. The quantity of water which the drains are designed to carry and the pumps to lift is $2\frac{1}{2}$ cubic feet per second for each square mile. The drains will be laid 7 feet deep, their size being proportioned to the area which may be drained into the separate lines. For the purpose of making the drains accessible, so that they may be kept free from silt and roots, manholes constructed of redwood lumber, $2\frac{1}{2}$ by 4 feet, reaching 18 inches below the flow line of the drain, are placed at intervals of 400 or 500 feet. The necessity for this provision is quite apparent from an inspection of tile drains which have been laid in the vicinity. Local experience is that if the drains be laid 16 feet distant from a line of trees or vines but little difficulty from roots entering drains would be found. But this condition can not be met in this system of drains; so that it will be necessary to make ample provision for the constant scouring of the drains. They should be laid upon a board bed, and provision has been made for this in the estimates. No provision is made in the estimate for the purchase of right of way for drains, since any inconvenience or loss resulting to land during construction will be more than compensated for by reason of the proximity of the drains to the fields of the owners who will be inconvenienced.

ESTIMATE OF COST.

The newness of this class of work here, and the difficulty of getting at the probable prices at which large drain tile can be obtained, give an uncertainty to the estimate for this plan. In this estimate the cost of pumping plant, manholes, material, labor, organization, legal fees, engineering, and superintendence have been provided for; also, a liberal price has been allowed for excavation because of the unknown and indeterminate part which hardpan and caving soil will play in the construction work.

The following units of cost have been used in making the estimate of the cost of the execution of Plan No. 2:

Cost of tile drains per lineal foot.

	SIZE OF TILE.							
	8-inch.	10-inch.	12-inch.	14-inch.	16-inch.	18-inch.	20-inch.	22-inch.
	Cents.	*Cents.*	*Cents.*	*Cents.*	*Cents.*	*Cents.*	*Cents.*	*Cents.*
Cost of tile at Fresno	$13\frac{1}{2}$	$22\frac{1}{2}$	27	40	50	60	70	85
Other costs	$19\frac{1}{4}$	$20\frac{1}{4}$	$21\frac{1}{4}$	$23\frac{1}{4}$	$23\frac{3}{4}$	$25\frac{1}{4}$	$29\frac{1}{2}$	33
Total	$32\frac{3}{4}$	$42\frac{3}{4}$	$48\frac{1}{4}$	$63\frac{1}{4}$	$73\frac{3}{4}$	$85\frac{1}{4}$	$99\frac{1}{2}$	118

Cost of manholes, estimated at $1\frac{1}{2}$ cents per lineal foot drain; sumps at pumping stations, $90 each; pumping plants, $1,200 for the smaller and $1,600 for the larger subdistricts. To the total cost of construction 5 per cent is added to cover incidental expenses, such as organization, engineering, etc., which can not be itemized but which are a legitimate and necessary part of the cost of the completed work.

Under this plan the subdistricts are designed and estimated as units of the whole and the cost per acre of the territory included in each does not in any way depend upon that of an adjoining subdistrict. Striking an average of the several subdistricts, the cost per acre is estimated at $14.16. In this system all drains are of tile, and labor and material estimated at present quotations. While the cost varies somewhat for the different subdistricts, this may be regarded as a fairly accurate estimate under existing conditions of values. There will be approximately sixty miles of drains, making it a work of such magnitude that it will enlist the best efforts of contractors. Each of the separate subdistricts will require from 10,000 to 31,000 feet of draintile, ranging from 8 to 22 inches in diameter. With respect to the estimates of the cost of both plans it should be said that a more minute canvass and examination of all the details will probably result in a reduction of the estimates. It is intended to present the case fairly and to name figures that will cover the cost. In the consideration of new work for which there is no local price established the tendency is to underestimate rather than otherwise. A cost of from $13 to $14 an acre on all land included within the limits of a district containing from 17,000 to 20,000 acres may be regarded as an outside estimate with a reasonable prospect of the final cost being 20 per cent less.

COMPARISON OF THE TWO PLANS.

Plan No. 1 disposes of water by gravity into a large intercepting outlet constructed for the purpose which will discharge the water into the flat leading into the Fresno Slough. Plan No. 2 gathers water into sumps at convenient points by means of tile drains and discharges it by suitable pumps into existing irrigation canals. In both instances the lowering of the soil water is to be accomplished by parallel drains, one-half mile apart and from 5 to 8 feet deep. In the former plan land will be taken up by open ditches, and they must be crossed by irrigation canals, public and private roads, and railroads, and provision must be made for constant repairs and cleaning. In the latter plan no land need be provided nor bridges built and maintained, but ample provision must be made for scouring the drains and for operating the pumps. This expense where several subdistricts are operated under one management may be placed at 25 cents per acre annually. In Plan No. 1 the work should be organized and executed as a unit and possesses the advantage that each drain may be extended farther east

and be made available for an extension of territory at any time the people may so desire. In Plan No. 2 as many subdistricts may be formed into one district as desired and the work of each subdistrict be complete in itself. The difference in the cost of the work under the two plans as estimated is not enough to enter seriously into the discussion of the plans, but as far as cheapness is concerned the chances are in favor of the second.

THE EFFICIENCY OF THE TWO PLANS.

There seems to be no evidence to show that either open or closed drains will fail to lower water in seeped soils. Experience in Colorado with either kind of drains is satisfactory in that respect. Observations upon the water line made in March, 1903, for a distance of 3½ miles along Fruit avenue indicate that the rise is mainly uniform at different points, and that while these points do not form a straight line they readily show that if drains were placed at the one-half-mile lines as directed in the plans described, the water line would lower between them with as great uniformity as it now rises when there is no drainage. It may be said in favor of the open-drain system that the ditches are made large, not because it is expected that the drainage to be provided for will require their full capacity, but for reasons of construction and maintenance. They can not be kept open unless they have sufficient bottom width to permit workmen to readily clean them, and further, ample bottom width will give room for some temporary obstructions caused by crumbling sides without wholly obstructing the ditch. For this reason there will be but slight risk of overcharging the capacity of the ditches. The capacity of the tile system will be limited to the amount of drainage which it is computed to carry, which is, as before stated, 2½ cubic feet per second for each square mile.

The data thus far secured regarding the quantity of water which should be removed from the soil daily are not as complete and reliable as could be desired. The only definite measurements upon the rise of the water table were obtained in March, 1903, from test wells located half a mile apart along Fruit avenue, beginning at Church avenue and continuing south. The rise noted at the several wells at the end of 30 days was as follows:

	Inches.
Well No. 1	18
Well No. 2	13
Well No. 3	16
Well No. 4	11
Well No. 5	17⅜
Well No. 6	18¾
Well No. 7	15

From this record it appears that the daily rise during the month of March was one-half inch, which is greater than information previously

obtained had given reason to believe. Should this prove to be a fair criterion for computing the capacity of the drainage channels required, it may be found that the tile system will be overcharged. There are indications, however, that the water in some localities passes downward to lower levels through channels in the soil occurring at irregular intervals so that drains which collect water from one locality may part with it at another before it reaches the final outlet.

USE OF DRAINAGE WATER.

The water which will be developed by any drainage system may be useful for irrigation whether delivered to a ditch provided especially for the purpose or mingled with the water in the irrigation canals. From the information thus far obtained it is believed that in this region such waters may be safely used for irrigation.

SUMMARY.

This is the case briefly stated. The attempt has been made to present the facts gathered in such a manner that the conclusions reached can be understood by all. The drainage of these lands is practicable, though not without difficulties. The worth of the product of the land, together with its value for homes, makes it well worth the cost. The land which has suffered greatest injury is that which is regarded most highly for the cultivation of vines. The fertility of the soil is unquestioned. The use of expensive fertilizers will not be required. No serious disadvantage attends the cultivation of this vineyard soil except its lack of drainage. While this difficulty was unlooked for when the land was first improved, it is not one which may not be overcome, nor will the expense of the necessary work be greater than has been incurred for similar improvements elsewhere on land much less valuable and which is now considered by the owners a most profitable and satisfactory investment.

Recommended for publication.
A. C. True, *Director.*

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